



Qualimetric Assessment of Students' Research Competence within the Context of Education Informatization

Olga Popova^{1*}, Dmitry Romanov¹ and Marina Evseeva²

¹Kuban State Technological University, Krasnodar, Russia.

²Kuban State University, Krasnodar, Russia.

Authors' contributions

This work was carried out in collaboration between all authors. Author DR substantiated the study relevance, managed the analysis of literature, set the aim and tasks of the study, designed the study (collected empirical data on students' research activities) and came up with conclusions and practical recommendations based on the findings. Author OP singled out assessment criteria of motivational and behavior components for students' research competence. Author ME managed processing the empirical data and interpretation of the experimental results. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Is building a model for assessing students' research competence.

Study Design: Experimental testing of the assessment model for students' research competence.

Place and Duration of Study: Students (n=648, 2009, 2010 и 2011 enrolment years) at technical university – Kuban State Technological University.

Methodology: Used methods: Systemic approach, qualimetric approach, competence approach (targets students at effective use of the obtained knowledge and skills, to settle successfully living, social and professional tasks), metasytemic approach (a portfolio is viewed as apically implicit system comprising relatively autonomous components), synergetic approach (development of students' research competence is viewed in integral relation with their professional self-

*Corresponding author: E-mail: popova_ob@mail.ru;

organization and self-development) and student-centered approach (a learner's priority is manifested in educational process).

Results: Decision rules (AI term) for integrated assessment of research competence are as follows:

1. If cognitive, operational, motivational and behavior components are registered high, and reflexive component is medium and up, in this case, the level is marked as creative.
2. If at least one component (except reflexive) is registered very low, the level is marked as immature.
3. If motivational component is registered low, and cognitive, operational or behavior ones are in between low and medium, the level is marked as situational.
4. If all components are registered medium (reflexive can go low), the level of competence is marked as literate.
5. If two or three components are registered high, the rest are medium and up, the level is marked as scholarly.

Conclusion: The suggested criteria and levels represent an integral component of criteria and assessment framework for psychological and pedagogical monitoring (monitoring of personal and professional development of students) and a basis for forecasting personal and professional growth of students. With informatization of professional education it is possible to assess students' research competence on the basis of keeping a portfolio.

Keywords: Research competence; educational research activity; student; behavior component; portfolio; informatization; assessment.

1. INTRODUCTION

No doubt that progress in science and technology of any human activities is a crucial factor in economics, enterprise competition, regions and states [1]. An effective enterprise, affective human activity, effective economy need an efficient specialist who possesses skills in research, analysis and methodology (the last is necessary for implementation of innovations). Henceforth, preparing such specialist is a state social order placed with educational system and is one of the cutting edge tasks in professional training of any kind. To be ready for some activity means to possess skills to function as the subject in that activity [2]. Nowadays, educational technologies are rapidly developing to form students' research competence, i.e. to form their readiness for research [3-7].

On the other hand, the interrelation between readiness for research and individual's innovative potential remains understudied; models for both research competence assessment, in general, and its behavior component (the most important component!), in particular, are poorly developed. Modern information technology makes it though really possible. The above-mentioned conditions hinder appearance of the science-based educational technologies aimed at simultaneous development of students' readiness for research activities and other skills (comprising social and professional competence). The problem of the study is finding out an answer to the question:

how to assess objectively students' research competence? The aim of the study is building a model for assessing students' research competence. Tasks of the study:

1. To identify evaluation criteria of the assessment of behavior and motivational components of students' research competence.
2. To determine experimentally the degree of significance of the suggested criteria.
3. To formulate the rules of assessment (identification) of general level of development of students' research competence.

The achievement of the aim and completion of its subordinated tasks are important due to the growing role of research competence of a specialist (engineer) in the modern world, the need to strengthen the orientation of higher education onto the formation of students research competence.

Analysis of the existing models of research competence (readiness for research activities) revealed that it is a systemic personal and professional quality as it includes not only knowledge and skills, but appropriate motivation, values, interests and personal experience of research activities [8]. According to modern views it comprises six components: cognitive (knowledge determining readiness to deal with research problems, primarily the knowledge of

types of research problems and scientific methods), orienting (an array of abilities to detect needs in knowledge and search for ways to get it under the circumstances), technological (an array of skills to take steps to solve research tasks), values and motivation (reasons for research activities and personal attitude, realizing its importance for one's own future), reflexive (ability to analyze one's own research activities) and behavior (learner's personal experience in research); navigating and technological can be combined into one – operational. Behavior is recognized to be the dominant component as it is due to this component that appropriate knowledge, skills and motivation make sense. Nowadays, levels in research competence development have been determined by specialists: creative (supreme), educational attainment, literacy, situational and zero level. Higher levels of research competence suggest its linkage with other skills, personal and professional qualities (e.g. IT competence, i.e. ability to make use of computer technologies to settle life, social, professional and academic tasks), its simultaneous development along with social and professional competence in general [9].

No doubt, the most important factor in forming research competence is scientific research activities (SRA) and academic research activities (ARA) of students. Some specialists single out theoretical and practical activities (TPA) as an interim stage between SRA and ARA [10]. The main resemblance between TPA and ARA is their compulsory status, whilst their distinction is continuity of results at various stages of educational process. According to the authors of this paper, such continuity will not only ensure the integrity of students' research activities, but it will also provide consistency of the educational process (professional training) in general.

No doubt, modernization and informatization of education hold new perspectives (possibilities) for creativity and research activities of students. Implementation of innovative learning methods (e.g. projects) and introduction of new monitoring forms for academic and professional work of students (e.g. portfolios) are possible due to combination of pedagogical and information technologies [11,12]. Within the context of education informatization due to implementation of innovative teaching techniques, it is possible to carry out monitoring of students' academic and professional work. Thus, electronic portfolio, comprising their creativity and research activities,

as well as their documentary proofs, is a result of combination of pedagogical and information technologies. The idea of launching electronic science and technology journals for youth on the basis of university portals was fairly interesting. This undertaking facilitates cooperation between science, education, business and manufacturing, i.e. integration of educational and research activities [13]. Thus, there are currently favorable conditions for building monitoring systems of students' research competence development, in general, and its objective assessment, in particular.

2. MATERIALS AND METHODS

Methods and approaches used in the study: systemic (research competence is viewed as a systemic personal and professional property comprising knowledge, skills, motivation, attitudes and values, personal research experience), qualimetric (the maturity of behavior component of research competence is viewed as a latent variable defined by a set of indicators – partial criteria), competence approach (targets students at effective use of the obtained knowledge and skills, to settle successfully living, social and professional tasks), metasystemic approach (a portfolio is viewed as apically implicit system comprising relatively autonomous components), synergetic approach (development of students' research competence is viewed in integral relation with their professional self-organization and self-development) and student-centered approach (a learner's priority is manifested in educational process). The leading methods among them are systemic and qualimetric approaches: the former helps to identify components of research competence to be measured; the latter is used to define evaluation criteria, making emphasis on multi-criteria assessment.

To achieve the intended goal, we have used the following research methods and techniques: analysis of scientific and methodological works, relevant regulatory documents and best pedagogical practices, modeling, multiparametre analysis of systems, qualimetric methods, pedagogical experiment and statistic techniques (methods of math statistics). The major part in this study was given to qualimetric techniques – owing to their application assessment criteria for motivational and behavior components of students' research competence have been singled out on the basis of modern views on research competence and its components. The

pedagogical experiment together with methods of math statistics was necessary for evaluating the suggested assessment criteria for motivational and behavior components of students' research competence.

In this study we suggest that the maturity of behavior and motivational components of research competence should be viewed as latent variables defined by a set of partial indicators (indicator variables). The method of processing indicator variables for qualimetric assessment of latent is presented in [12]; the evaluation of latent variable was performed on the standard logarithmic logit scale (interval scales). The importance of the suggested indicators for assessing behavior and motivational components of readiness for research activities was being evaluated in the course of experimental work with students (n=648, 2009, 2010 и 2011 enrolment years) at technical university – Kuban State Technological University. The correlation coefficient of each indicator variable and latent was calculated. The indicator variable was considered critical (fundamentally important) if the correlation coefficient was 0.7 and higher, otherwise – important. The stages of students' research competence formation (components of pedagogical technique, its realization, to be specific) coincided with those presented in [14-17], i.e. propaedeutic, stimulating and developing.

We believe that performance and cognitive component of research competence, as well as the degree of personal-professional skills (the interrelation between performance and behavior is taken into account), can be determined on the basis of methods suggested in papers [14]. Therefore we have identified assessment criteria of motivational and behavior components of research competence.

Let us consider indicator variables for assessing the behavior component of research competence.

Π_1 parameter is the effectiveness of research activities:

$$\Pi_1 = W_1 + 0.8 \cdot W_2 + 0.6 \cdot W_3 + 0.4 \cdot W_4 + 0.2 \cdot W_5,$$

where W_1, W_2, W_3, W_4, W_5 , respectively, is the number of research papers of high quality, proper quality, the number of theoretical and practical studies, the number of training research papers of high and proper quality. Π_2 parameter is the consistency of research activities. A

portfolio can be presented in the form of a directed graph [2], whose vertices are the results and arcs are relations between them. From the point of well-known theory of sets and relations, a portfolio can be presented as follows:

$$\beta = \langle D \ F \ G \ A \rangle,$$

where D, F and G , respectively, is a set of materialized results of educational and training activities, supporting materials and documentary proof of the results. A is a set of relations between them. For instance, a student may win a medal for a research project in a regional competition. Ideally, the portfolio must represent a connected graph (i.e. without isolated vertices), as it proves the wholeness (consistency) of the student's educational and training activities (in general) and research activities (in particular). In this case,

$$\Pi_2 = \frac{P(A)}{P(D) + P(F) + P(G)},$$

where P is the power of set.

The consistency of students' research activities (continuity at different stages) can be seen in the following aspects. Firstly, earlier ARA papers can be transformed into a TPA study. For instance, throughout university studies a student may produce (in the form of a project) ARA papers on 'Economic problems of my area present development', 'Social problems of my area present development' and 'Political problems of my area present development', which can be united into a paper on 'Problems of my area present development'. Secondly, these earlier ARA papers, as well as gained knowledge and experience are a solid ground for further research. For instance, an ARA paper on 'Algorithms of finding a ratio of amplitudes and phase difference distorted by harmonic signals' can become a basis for a TPA paper on 'Finding errors in amplitude ratio and phase difference of distorted signals by means of curve approximation and overlay signals', which in turn can develop into a SRA paper on 'Scientific foundations of designing a digital analyzer in microwave circuits'. Another example – an ARA paper on 'Akhmedkhan-Sultan, twice Hero of the Soviet Union (an airport in Kaspiisk, the republic of Dagestan, was named after him) can grow into a TPA paper on ' Heroic deeds of soldiers of Northern Caucasus in Great Patriotic War (World War II). Thirdly, new methods can further be applied in addressing old challenges. For

instance, studying Computer Science a first-year student has prepared a presentation on 'Krasnodar is a cosmopolitan city'. Studying Multimedia Technologies in the 3rd year, he/she has made an animated film on the same subject. SRA works must also result in publications and other proof of qualification degree. As any complex system, a TPA paper and SRA paper can be produced only by combining and upgrading an ARA paper (this paragraph can be omitted in case of shortening the paper).

Π_3 parameter is productivity of obtaining tangible results of research activities:

$$\Pi_3 = \frac{P(F) + P(G)}{P(D)}.$$

Π_4 parameter is productivity of applying scientific methods in research activities:

$$\Pi_4 = \sum_{i=1}^{P(Q)} \sum_{j=1}^{P(D)} q_{i,j}.$$

Here Q is a set of research methods used by a student (in general), q_{ij} is productivity (from 0 to 1.0) of application of i-method obtaining j-result of portfolio (if the method has not been applied, $q_{i,j} = 0$). Π_5 parameter is variety of application of research methods a student has used: the variety coefficient equals R, if a student has applied R-number or more methods which has yielded R-number or more research activities results (it is calculated similarly to h-index). Similarly to that, Π_6 parameter and Π_7 parameter are worked out – productivity and variety of applied means of research activities, respectively (e.g. software, measuring equipment, etc.) Π_8 parameter is an expanse of research and application and regulatory and documentary bases, that a student has used when carrying out research activities - (articles, course books, research theses, etc.), any other intellectual property, legal instruments, etc.

Π_9 parameter is a share of knowledge and skills which do not relate to research competence and which a student has applied when doing ARA, SRA and TPA projects:

$$\Pi_9 = \frac{P\left(\bigcup_{j=1}^W u_j\right)}{P\left(\bigcup_{j=1}^K U_j\right)}, \quad W = W_1 + W_2 + W_3 + W_4 + W_5,$$

where U is a symbol for all sets, P is a power of a set, K is a number of skills and personal-professional properties the student obtains (except the very readiness for research activities), W is a number of research projects completed by the student, U_j is a set of knowledge and skills relating to jth competence, u_j is a set of knowledge and skills which the student has applied when doing jth research paper. The given parameter reflects the relation between the student's research competence (to be more exact, its behavior component), other competences and personal-professional properties (to be more exact, their operational components). In its essence, student's research activities are the supreme form of manifesting common cultural and professional competences (knowledge and skills, in the narrower sense). It is the competence approach that compels a student to make use of their knowledge and skills serving as tools in academic and professional activities. The research activities are the highest form here. Π_{10} parameter is the volume of extra knowledge and skills (i.e. beyond the educational programme) which the student has got owing to research activities. In modern conditions, it is extremely important not only to find the right professional direction in life, but elimination of 'gaps' in training that hinder the realization of that choice [10]. For instance, a software engineer lacks knowledge in food industry where he/she is going to be employed, and he/she has to study a rapid food deterioration assessment method. Obviously, the suggested set of variables must be eventually supplemented and amended.

3. RESULTS AND DISCUSSION

With the aim of assessing the motivational component, we will specify indicator variables. Let R – a student's research activity rating (it can be considered, in a simplified manner, equal to Π_1 variable), then the average tempo of gaining experience in research activities is

$$R(C) = \frac{R}{T}.$$

T is training time (Bachelor's Degree – 4 years, Master's – 2 years, Specialist's full time study – 5 years, Specialist's part time – 6 years). The training time can also be measured in number of terms. Obviously, the success of a student in research activities depends on accumulated knowledge and skills provided by the curriculum, on operational component – the readiness for research activities (knowledge of scientific

methods and ability to apply them), on accumulated personal experience in research (behavior component). Addressing the given problem, it is quite obvious that creativity promotion and student's research skills enhancement are in direct relation to the amount and level of research in the past.

Thus, by means of the ratio of student's research effectiveness in later times $R(C)_2$ to the same parameter of the earlier period $R(C)_1$ we will get the coefficient of experience accumulation in independent creative activity:

$$KHO = \frac{R(C)_2}{R(C)_1}.$$

As the Bachelor's training takes place within 4 years, it is possible to present variants of experience accumulation of independent creative activity (Table 1). The experience accumulated in earlier periods is suggested to be referred to as 'training', at later stages – 'crediting'.

As it is seen from Table 1, the first variant is the most difficult one, the time of experience accumulation is only one year, whereas the time of its application – the following three years. The least difficult is the third variant with its three-year time of experience accumulation and one-year time of its application. Thus, in the order of difficulty decrease the coefficients of experience accumulation will look like:

$$KHO_1 = \frac{R(C)_{BCD}}{R(C)_A}, \quad KHO_2 = \frac{R(C)_{CD}}{R(C)_{AB}},$$

$$KHO_3 = \frac{R(C)_D}{R(C)_{ABC}}.$$

It is known that the less creative (research) activity experience is gained, the more difficult it is to develop and accumulate. The coefficient for research and creative activity experience development can be presented as a ratio of the most difficult to the least difficult accumulation:

$$KP = \frac{KHO_1}{KHO_3} = \frac{R(C)_{BCD} \cdot R(C)_{ABC}}{R(C)_D \cdot R(C)_A}.$$

In a more simplified manner it looks as follows:

$$KP = \frac{R(C)_{CD}}{R(C)_{AB}} = \frac{R_{AB}}{R_{CD}}.$$

Here R_{AB} and R_{CD} are student's training ratings in research activities in the first two years and the last two years, respectively. This parameter is the first criterion for the motivational component of research competence M_1 , as with certain training (both accumulated personal research experience and maturity of certain competences which do not refer to research activities directly) the further speed of experience accumulation largely depends on motivation and valuing definite activity [12]. The parameter

$$M_2 = \frac{Z''}{Z'},$$

where Z'' и Z' are operating component of research activities at the final stage of training and at the initial (at the end of the first year of training), respectively. The first two indicators show indirectly the level of motivational component of research competence.

Now we will suggest the evaluation model for the third indicator - M_3 for motivational component of research competence. Let N_{cons} , N_{prag} and N_{crit} are numbers of those conscientious, pragmatic and critical of their research activities, respectively, then the motivation index here is

$$M_3 = \frac{\sum_{i=1}^{N_{cons}} B_i^{cons} + 0,5 \cdot \sum_{i=1}^{N_{prag}} B_i^{prag} + 0,25 \cdot \sum_{i=1}^{N_{crit}} B_i^{crit}}{B}.$$

Here: B is points (according to some linear scale, e.g. centigrade scale), showing the degree of the first motive. Weight coefficients in the numerator '1', '0.5', '0.25' and '0' point out the degree of importance of the motives connected with conscientious, pragmatic and critical motivation: the most powerful motives are conscientious (the student is aware of the importance the research has for their future, sees the connection with their competitiveness). Motives for research activities and sociological methods of their assessment are presented in [13].

For automation of monitoring process of students' research and creativity (it is this monitoring information that is the basis for assessment of all components of research competence), the authors in collaboration with a group of highly qualified programmers of Kuban state university have designed 'PORTFOLIO' software. It enables students to create and modify their e-portfolios. This computer program includes 6 blocs: managing bloc, personal info

Table 1. Variants of complete and incomplete accumulated experience

Variant	Complete accumulated experience		Incomplete accumulated experience		Degree of difficulty
	Unit	Time	Unit	Time	
1	A	1	BCD	3	High
2	AB	2	CD	2	Medium
3	ABC	3	D	1	Low

bloc, performance bloc, performance assessment bloc, competence info bloc, portfolio coordination bloc. Managing bloc is designed for general coordination of the application. Portfolio coordination bloc enables one to build a directed graph – cognitive model (reflection) for the student’s academic and research outcomes in their correlation. It is the performance assessment bloc that calculates the suggested parameters.

The system works with information support – a database on students and their academic training (creativity and research) performance. The information support comprises basic data on students, specializations and trainings, subjects and competences, students’ achievements in research and creativity projects and their correlation, on methods and tools applied, on links to online resources, etc. It is no doubt that the use of e-portfolios and monitoring technologies (personal and professional growth of students monitoring) requires an adequate level of IT competences from both students and teachers [14].

In the course of lab work correlation coefficients of indicator variables with latent both for behavior component (Table 2) and motivational component (Table 3). It is obvious, that the most important indicators of behavior component in research competence are $\Pi_1, \Pi_4, \Pi_8, \Pi_{10}$; the rest of them can be deemed as significant (important). For evaluation of the motivational component the variables M1 and M3 are crucial; a rather low correlation coefficient of the second indicator with the latent variable is due to the fact that the majority of research methods and techniques can be mastered by students in the first two years of training, namely, when studying fundamental subjects (physics, for instance).

Application of monitoring techniques (informatization of education creates all possibilities for that, including e-portfolios) makes it possible to carry out integrated assessment of competences and personal-professional skills [15].

Table 2. The correlation of indicator variables with estimated value for behavior component of research competence

Variable	r	Variable	r
*** Π_1	0.88	* Π_6	0.58
* Π_2	0.56	* Π_7	0.53
** Π_3	0.64	*** Π_8	0.84
*** Π_4	0.77	*** Π_9	0.64
** Π_5	0.67	*** Π_{10}	0.92

*** - Very high, ** - High, * - Medium, r – Correlation coefficient

Table 3. The correlation of indicator variables with estimated value for motivational component of research competence

Variable	r
*** M_1	0.82
* M_2	0.65
** M_3	0.89

*** - Very high, ** - High, * - Medium, r – Correlation coefficient

Decision rules (AI term) for integrated assessment of research competence are as follows:

6. If cognitive, operational, motivational and behavior components are registered high, and reflexive component is medium and up, in this case, the level is marked as creative.
7. If at least one component (except reflexive) is registered very low, the level is marked as immature.
8. If motivational component is registered low, and cognitive, operational or behavior ones are in between low and medium, the level is marked as situational.
9. If all components are registered medium (reflexive can go low), the level of competence is marked as literate.
10. If two or three components are registered high, the rest are medium and up, the level is marked as scholarly.

As for all partial combinations of decision rules (total $4^5 = 1024$), it is impossible to dwell on them due to the article volume limitations.

The practical significance of the outcomes is in the fact that the identified criteria and levels are an integral part of the criteria assessment apparatus for psychological and pedagogical monitoring (students' personal and professional development monitoring) and the basis for forecasting students' personal and professional development. The outcomes substantiate the technology of pedagogical support of students' research activities inside transdisciplinary educational process, which includes the following stages: singling out elements of theoretical courses (academic subjects), covering the same areas as their academic research activities (ARA), theoretical and practical activities (TPA) and scientific research activities (SRA); drawing up work programmes of academic disciplines, reflecting the place of students' research work in the educational process; formulating headings for their academic research activities (ARA), theoretical and practical activities (TPA) and scientific research activities (SRA); appraising the difficulty degree of such projects and determining a variety of tools needed for their completion (e.g. software for statistical data processing); monitoring, assessment and forecasting students research outcomes; timely assistance in overcoming difficulties when carrying out research activities; replenishment of online educational resources (at chair's or educational institution's e-domain) by support methodology information and the research outcomes; assistance to a student in personal and professional development. The didactic efficiency of this technology is reflected in the paper [2].

4. CONCLUSION

Informatization of educational process (first of all, integration of pedagogical and information technologies) creates favorable conditions for facing many challenges, the assessment of students' research competence included. The prospects of this study lie in building probabilistic information models for students' research competence development (on the basis of probabilistic-statistical approach), as well as studying possibilities of evolution calculation methods (genetic algorithms) for modeling and assessment of such important aspect as continuity in students' research activities. After

analyzing our findings we have arrived at the following conclusions:

The necessity of identifying motivational and behavior components of research competence results from discrepancy between the importance of monitoring students' personal and professional development and lack or insufficiency of methods for objective assessment of critical components of the afore-mentioned personal and professional property.

The methodological basis for identifying a set of indicators for evaluating motivational and behavior components of research competence is the qualimetric approach, the scientific – existing models of this personal and professional property.

The suggested sets of indicators for motivational and behavior components of research competence meet the requirements of operability, functional completeness and non-redundancy.

The integrated assessment of students' research competence is based on quantitative evaluation of all components of the afore-mentioned personal and professional property and on the application of decision rules.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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